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This issue contains articles on the following subjects: 1.Making Human Factors Truly Human Factors; 2.U.S. Nuclear Regulatory Commission NUCLARR Database; 3.Modeling Human Force Response (Concluding Series); 4.Multi-User Human Computer Modeling - A Mixed Blessing; 5.Future Performance Measurement Needs;

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VOLUME II: NUMBER 3, SUMMER 1991

CSERIAC GATEWAY

PUBLISHED BY THE CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER

In this issue:

Page

CSERIAC is a United States Department of Defense information analysis center hosted by the Armstrong Laboratory, Wright-Patterson Air Force Base, Ohio, and operated by the University of Dayton Research Institute.

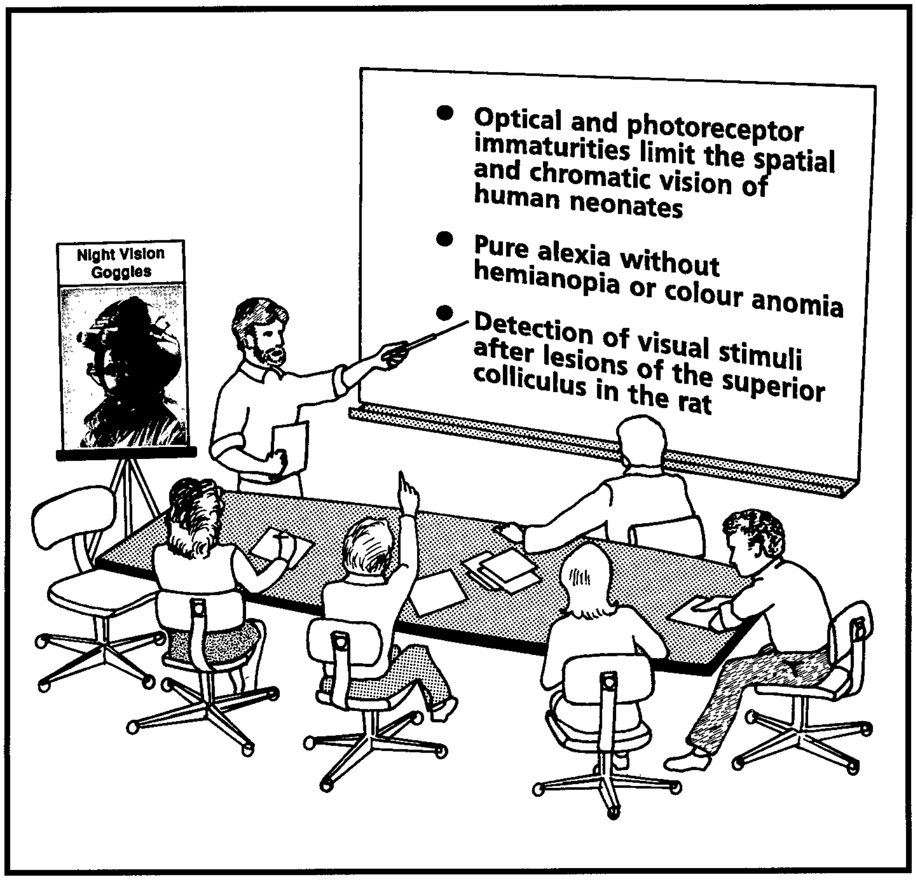


Figure 1. "How will these vision studies help us to improve night vision goggles?"

Making Human Factors Truly Human Factors

Alphonse Chapanis

Human factors seems to suffer from a never-ending identity crisis. The root of the problem, it seems to me, is that we have not clearly established in our minds exactly what human factors is, and what it is not. Take a look at the publication called *PsycSCAN: APPLIED EXPERIMENTAL & ENGINEERING PSYCHOLOGY*, a collection of abstracts published periodically by the American Psychological Association. In one issue of that publication I found these titles under the heading of "Human Factors & Ergonomics":

- Optical and photoreceptor immaturities limit the spatial and chromatic vision of human neonates
- "Pure alexia" without hemianopia or colour anomia
- Detection of visual stimuli after lesions of the superior colliculus in the rat; deficit not confined to the far periphery
- Is obesity an eating disorder?

Continued on page 2

• Hypnotic susceptibility, visual distraction, and reports of Necker cube reversals

What a hodge-podge of miscellaneous and irrelevant studies all classified under the heading of "Human Factors & Ergonomics"! Lest there be any misunderstanding, I am not criticizing the content of any of these studies. What I deplore is their inclusion in the category of human factors. No wonder people are confused about what we do (See Fig. 1)!

Let's start with something very basic: Exactly what do we do? Human factors has been defined in several ways. My definition is that:

> *Human factors is a body of knowledge about human abilities, human limitations, and other human characteristics that are relevant to design.*

What we do is *human factors engineering*, which I define this way:

> *Human factors engineering is the application of human factors information to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use.*

I don't want to enter into an extended discussion about the differences between *human factors* and *ergonomics*. Frankly, I think the differences, such as they are, are unimportant and the arguments that have sometimes raged about them have been largely fruitless and a waste of time and energy. Whether we call ourselves human factors professionals or ergonomists is mostly an accident of where we happen to work and where we were trained. We are all — human factors professionals and ergonomists — ultimately concerned with trying to shape the technological world in which we live so that it will better suit us and our needs. That's the common bond between us and that, in the final analysis, is all that matters.

To return to my definition of human factors and human factors engineering, the significant word in those definitions is *design*, because it is this that distinguishes us from such purely academic disciplines as psychology, physiology, and anthropology. Our aim is to apply what we know to the design of practical things — things that we have to do or have to use because of our occupations, or things we want to do or want to use because of our inclinations.

If there are design implications in what we do, it is our responsibility to say what they are...I would endorse a requirement that every manuscript submitted to *Human Factors* or *Ergonomics* should have a final section headed *Design Implications*.

The implications of this point of view are that research, even so-called basic research in human factors, should be oriented toward the design of something. If the findings of that research don't contribute or lead to design recommendations, then the research, no matter how good or how interesting it may be in its own right, has no place in the human factors literature. Let me illustrate with an example.

I read a study in which brain potentials were recorded from a number of locations on the scalp. Subjects were asked to direct their attention, without moving their eyes, to flashing stimuli in one of three locations in the visual field. The evoked brain potentials correlated with the locus of the subject's attention. No design recommendations were made, and, frankly, I don't see that any could have been made. It did not belong in the *Human Factors* journal. Articles such as this one communicate no human factors message because they have no such message to communicate. They dilute our literature and confuse those persons who happen to read our journals and who try to infer from them exactly what it is we do.

Another part of the problem is that we often fail to point out the design implications of our research when there are some to be made. I was once giving a lecture to an engineering audience and was talking about sensory thresholds: Absolute thresholds, upper thresholds, and JNDs — just noticeable differences. I had just shown some data on typical thresholds for several senses and was starting on my next point when I was interrupted by one of the engineers who asked, "That's all very interesting, buy why is it important for me as a design engineer to know all that?" Although my immediate reaction was that he was quibbling, I quickly realized that he was serious. The design implications were obvious to me, buy they were not at all obvious to him. I then managed to elaborate by saying that for many machine displays, energy levels had to be intense enough to exceed our absolute thresholds, but not so intense that they exceed our upper thresholds. Moreover, changes in energy levels had to be large enough to exceed our difference thresholds if we were to perceive them. I amplified by using as an example the beam of electrons striking the phosphorescent surface of a computer display terminal. That made sense to him and left him nodding his head in understanding.

The point of that experience is subtle but very important. I wasn't communicating a human factors message. I was talking about some properties of our sensory systems — as sensory systems. In other words, I was talking as a psychologist about what was to me an interesting psychological fact. My audience, however, was made up of engineers who were not interested in becoming psychologists. They had taken time out of their busy schedules to come listen to me in the hopes that they could learn something that would help them do their job better, that is, solve problems they had. They did not want to have to digest and deduce for themselves the design implications of what I was giving them.

All too often we professionals are guilty of failing to do that.

As one more example, I read a study that investigated the mechanical work and energy transfer both between and within body segments in doing a certain kind of work. The work involved is important because there is so much of it being done these days and because it involves a significant segment of our working population. The study was done with exemplary rigor and the article has tables and charts showing such things as patterns of total energy, and force and velocity curves as a function of movement time. Workers often experience strain and sometimes suffer injuries from doing this work. Yet, after presenting and discussing all their data, the authors made no attempt to tell us what this meant from a design standpoint.

On the basis of their study, how would they recommend redesigning the job to reduce the strains they measured? How could the devices these workers use be redesigned to ease their tasks? Could any supplementary aids be devised to help workers do their jobs? I realize that the research was not undertaken to answer those specific questions, but surely after all their work, the authors must have formed some ideas about these questions. Even if their design recommendations were tentative, they would at least call attention to some possible ways of improving a stressful and difficult job. As it stands, the study is merely an interesting one on the physiology of movement that happens to have been done in a working environment. There are human factors design implications there, but the authors have made no attempt to communicate them. We cannot expect engineers or designers to read our minds and deduce the design implications of what we have done. If there are design implications in what we do, it is our responsibility to say what they are.

These are only a couple out of many examples I could have used to make my point. To a considerable extent we have justly earned the criticism that we don't communicate our findings to practitioners and designers. This has happened because we sometimes fail to keep in mind the aim of our profession. I repeat: The reason we are in this business is to help design things. The reason we do our research is to find out how to design things better. Having done a study, the authors of it are best able to evaluate what it means for design, and if they claim to be human factors professionals, they have a duty to do just that. If no design implications at all can be drawn from a study, then it doesn't belong in the human factors literature.

I feel so strongly about this matter that I would endorse a requirement that every manuscript submitted to *Human Factors* or *Ergonomics* should have a final section headed *Design Implications* (see Fig. 2). If authors can't find any design implications in their work they should be encouraged to submit their manuscript to other journals.

To sum up:

- If we keep in mind that the only kind of research that belongs in the human factors literature is research that leads to design recommendations
- and if we are always sure to point out the design implications of that research
- we can all help to make human factors truly human factors.

Alphonse Chapanis is an independent consultant. Formerly he taught at Johns Hopkins University, and served as President of the Society of Engineering Psychologists, the Human Factors Society, and the International Ergonomics Association.

Figure 2. Requiring human factors journals to include a design implications section would enable engineers and designers to make better use of human factors data.

Chief Scientist's Report:

CSERIAC To Distribute Data From NAS/NRC Survey On Human Factors Specialists Education And Utilization

Donald J. Polzella

Our readers may recall an article on the National Academy of Sciences/National Research Council Committee on Human Factors, which appeared in the Fall 1990 issue of Gateway (Volume 1, Issue 4). The article, which was written by Study Director Harold P. Van Cott, described the Committee, its members, projects and products, and future directions.

The Committee will soon issue an important report on Human Factors Specialists Education and Utilization (National Academy Press, 1991). The report was prepared by a Committee Panel, which was tasked with recommending improvements for the education, training, and utilization of human factors specialists. The Panel had four major objectives: (1) to define the jobs and tasks performed by human factors specialists involved in the design, development, and production of integrated systems; (2) to identify the knowledge and skill requirements of human factors specialists; (3) to evaluate the extent to which human factors education and training currently satisfy the needs of industry and government; and (4) to assess and project the demand for and supply of qualified human factors specialists.

To accomplish these objectives, the Panel directed two extensive scientific surveys, one of human factors specialists (i.e., practitioners and supervisors) and the second of university-based human factors training programs. Among the important questions addressed were:

- What skills and knowledge are required by human factors specialists in performing their job-related tasks?
- To what extent are the human factors courses and programs in universities congruent with these task requirements?
- How qualified are recent graduates of human factors training programs?
- What is the number of students currently being trained in the human factors discipline, and what is the future projection?
- Is the supply of faculty in the various fields adequate to meet current and future needs?
- What actions can governmental and private organizations take to ensure an adequate supply of human factors specialists and faculty?

The surveys were conducted for the Panel by the Survey Research Laboratory of the University of Illinois at Urbana-Champaign and consisted of data obtained from 971 human factors specialists and 49 human factors graduate programs in the United States and Canada. Details concerning the methodology, results, and conclusions are contained in the Committee report. Among the more important recommendations made by the Panel were:

- Emphasize interdisciplinary graduate training;
- Base graduate training on a core curriculum augmented by other courses to meet specific educational objectives;
- Provide training for the development of supervisory skills;
- Encourage and develop graduate internship and traineeship programs;
- Focus research directly on interdisciplinary human factors engineering problems and not on traditional disciplinary approaches;
- Promote the human factors profession among women and racial minorities;
- Extend human factors applications to new areas.

Because of our mission to provide important and timely human factors/ergonomics information to government, industry, and academia, the Committee has requested that CSERIAC act as a distribution center for the complete survey results. The results are distributed on two DOS-compatible diskettes containing well-documented data files and SPSS-X command files for each survey. Also included are copies of each questionnaire and instructions on preparing the files for further analysis.

The cost of these materials is $25. To order, contact the CSERIAC Program Office. ●

Request for Topics For State-of-the-Art-Reports (SOARS)

CSERIAC makes every effort to be sensitive to the needs of its users. Therefore, we are asking you to suggest possible topics for future SOARS that would be of value to the Human Factors/Ergonomics community. Previous SOARs have included *Hypertext: Prospects and Problems for Crew System Design* by Robert J. Glushko, and *Three Dimensional Displays: Perception, Implication, Applications* by Christopher D. Wickens, Steven Todd, & Karen Seidler. Your input would be greatly appreciated. We are also looking for sponsors of future SOARs. CSERIAC is a contractually convenient, cost effective means to produce rapid authoritative reports.

Send your suggestions and other replies to Dr. Lawrence Howell, Associate Director CSERIAC Program Office, AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573.

The COTR SPEAKS

Reuben L. Hann

Editor's Note: Recently Reuben L. Hann was appointed as the new CSERIAC Contracting Officers Technical Representative (COTR), replacing Lt Col Philip A. Irish who took a position at Patrick Air Force Base, FL. We welcome Lew, as he prefers to be called, as the new CSERIAC COTR.

All good things must come to an end. So it is with the tenure of Lt Col Philip Irish, III as the CSERIAC COTR. Phil has been reassigned, but not before contributing a year and a half of outstanding service in providing technical contract management and spreading the CSERIAC "gospel." It was a genuine pleasure working with Phil. We will all miss him.

Having been associated with the government side of CSERIAC in various capacities since its inception, I bring a special perspective to my position as the new COTR. It has been exciting to watch CSERIAC grow and mature during the past two and a half years. The word is getting out to the users of ergonomic information that an organization exists which can provide timely, cost-effective answers to human factors questions, from "smart" bibliographic searches to convening a group of experts in a symposium setting.

In this issue of *Gateway*, we are pleased to present an article by one of the true pioneers in the field of human factors, Dr. Alphonse Chapanis. His thought-provoking commentary about the importance of the designer as the user of human factors information certainly strikes a sympathetic chord here at CSERIAC. Our mission is not to provide raw information; libraries and database services do that already. Rather, we provide information which the practitioner can really use. One of our products, the *Engineering Data Compendium*, provides this kind of assistance on every page. For problems which require more extensive search and analysis, our staff provides the value-added service of tailoring the answer to the needs of the user. For readers who might be unaware of CSERIAC's technical inquiry services, staff member Chris Sharbaugh summarizes them in this issue.

In this edition we present the third and final installment of the series of articles by Norm Phillips on modeling the human force response. This time he describes the inclusion of lateral (Gy) acceleration forces in the model.

A topic of increasing interest to human factor practitioners is human error. In her article, Erasmia Lois describes the U.S. Nuclear Regulatory Commission's NUCLARR database, which includes numerous functions for storing and analyzing human error, as well as hardware component failure rates. It is being used to develop risk assessments for nuclear power plants and other complex systems requiring high reliability.

Rick Davids of Lockheed describes the complexity of developing a new human computer model, the struggle to establish acceptance by the user community, and its successful application to real-world design problems.One of the services provided by CSERIAC is setting up and running workshops. Dr Robert O'Donnell chaired one such workshop, "Future Metrics and Models for Assessment of Human/System Performance in Advanced Military Systems." In this issue he presents a summary of the meeting and tells how you can acquire a copy of the proceedings.

CSERIAC Chief Scientist, Dr Donald Polzella, provides an update to a previous *Gateway* article about the National Academy of Sciences/National Research Council Committee on Human Factors. He recounts the results of two scientific surveys. I think you will find the recommendations quite interesting.

Once again, the variety of articles in *Gateway* reflects the multi-faceted world of human factors. The editorial staff tries to cover a broad spectrum of subjects in each issue; but if you feel we have missed an important topic, if you have an idea for an article, or would like to submit something you have written, please contact us. ●

Letters To The Editor

Dear Mr. Landis:

First, may I congratulate you on the style and presentation of CSERIAC *Gateway*. I find it infuriating, since this sort of publication is exactly what is needed in Air Traffic Control, and what I have been suggesting fruitlessly for about twenty years.

I was particularly interested in the article by Klein and Kinger in Vol. II No. 1. "Naturalistic Decision Making," which recalled a conclusion that I reached some years ago. I would like to send the authors the photocopy of a conference paper dating back to 1984, but I don't think that the address you gave (Yellow Springs, Ohio) would be enough for the US Post Office.

It appears that controllers have been making Recognition Primed Decisions, like the gentleman in Moliere who had been speaking prose for years without knowing it.

May I ask you to forward the copy to Klein Associates? I have several other papers and some reports of real-time simulations which would interest them, if they care to contact me.

Yours sincerely,

Dr. H. David
European Organization for the
Safety of Air Navigation
France

Readers are invited to submit article proposals, comments, and suggestions to: CSERIAC, Gateway Editor, AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573.

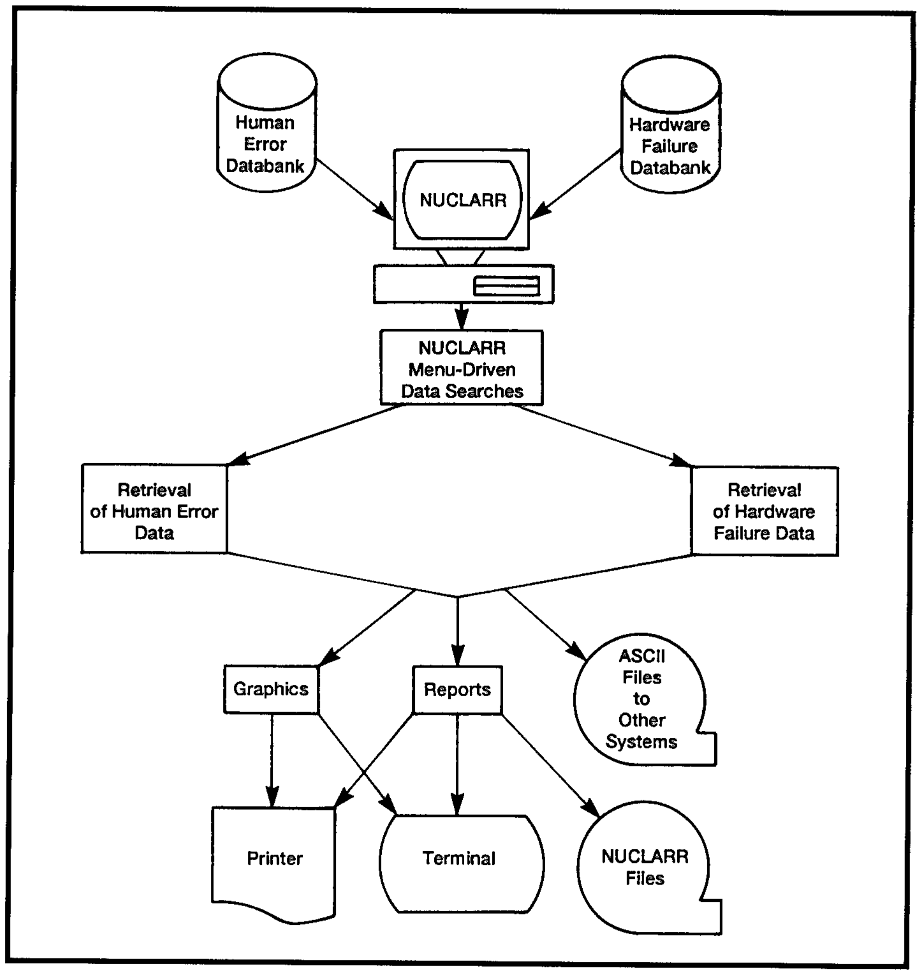
U.S. Nuclear Regulatory Commission
NUCLARR Database

Erasmia Lois

Estimates of human error probability and hardware component failure rates are used in probabilistic risk assessments (PRAs) of nuclear power plants (NPPs) and other complex high-reliability systems, because they provide useful information for optimizing system safety performance. The credibility and, therefore, the usefulness of these PRAs depend greatly on the availability of failure probabilities as bounding or anchor values for the PRA. Although there is an increasing recognition of the human error contribution to risk, it has not been treated comprehensively in PRA due, in part, to the lack of readily available bounding or anchor data. This has resulted in large uncertainties in the human reliability analysis (HRA) portions of PRAs and in an uncertain representation of the human contribution to risk. Therefore, the need existed for a readily available source of known human error and hardware failure probabilities. For this reason, the Nuclear Regulatory Commission (NRC) has developed the Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR), a personal-computer-based data management system which maintains a broad range of functions for storing, processing, and retrieving human error and component failure data in a ready-to-use format. NUCLARR is a user-friendly system, responsive to the varied needs of HRA/PRA analysts. It has been widely reviewed, revised, and upgraded to ensure accuracy, acceptability, and usefulness.

NUCLARR's major components are (1) the NUCLARR computer code, encompassing all the software for storing, processing, and retrieving human error and hardware failure data; (2) the NUCLARR Clearinghouse, composed of Idaho National Engineering Laboratory (INEL) personnel who maintain and upgrade the software and supporting documentation, and provide the primary interface and point of contact with users and data suppliers, including a hot-line function for on-call assistance; (3) the rotating Human and Hardware Reliability Analysis Groups (HHRAG), composed of PRA/HRA practitioners from domestic and foreign governments, industries, and academia, who, supported by INEL, are responsible for acquiring and screening human error and hardware component failure data for entry into the database; and (4) the rotating NUCLARR Review Committee, composed of subject-matter experts who independently review the data prepared for entry and that already reside in the database, and provide guidance for improving the database.

In summary, NUCLARR provides the process for acquiring and screening data, a data repository, data management system, and hot-line for on-call assistance. NUCLARR software capabilities include custom-tailored data searches; data aggregations based on



NUCLARR system configuration

well-documented statistical techniques; graphics; custom-tailored reports; and ASCII files for interface with other related computer codes (see Fig.).

Data for input to NUCLARR are acquired from a variety of sources: NRC sponsored PRAs; domestic utility PRAs; foreign utility PRAs; the academic literature; NRC technical activities involving data collection efforts; computer simulation trials; mathematical simulations; and applications of consensus expert judgment techniques.

The NUCLARR data are updated and distributed to the users on an annual basis. The NUCLARR system is documented in five volumes as NUREG/CR-4639. Volume I is the Technical Overview; Volume II is the Programmer's Guide; Volume III is the Guide to Data Processing and Revision; Volume IV is the User's Guide; and Volume V is the Data Manual.

NUCLARR is currently operating on PCs at several NRC locations. Non-NRC requests for access to NUCLARR are entertained when requestors provide data appropriate for input to the database. Thus the database resides in several DOE laboratories, domestic utilities or other related organizations, and foreign organizations such as the Commission of the European Communities, Italy; the Gesellschaft fuer Reaktorsicherheit (GRS), Germany; and the Nuclear Power Engineering Test Center, Japan. Currently NUCLARR includes over 2500 individual data records obtained from more than 60 different sources. Solicitation of appropriate data is a primary effort of the program; the NRC welcomes requests for access to the database in exchange for data appropriate for input to NUCLARR. You can take advantage of the NUCLARR database by contacting Paul Lewis of the NRC at (301) 492-3552, or David Gertman of INEL at (208) 526-0245.

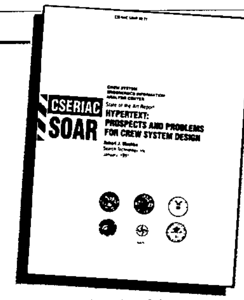
Erasmia Lois is a member of the Human Factors Branch Staff of the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC. ●

State-of-the-Art Report

HYPERTEXT

Prospects and Problems for Crew System Design

Robert J. Glushko
Search Technology



This informative report reviews the state of the art in the important new field of hypertext, an innovative concept for displaying information on computers that uses nonlinear methods for linking related information. Hypertext can significantly improve the accessibility and usability of on-line information for crew system designers and users. The report discusses:

Definitions and historical context: What hypertext is and why it has recently emerged as an important design concept.

Hypertext applications: How hypertext concepts can be applied in crew system design, including on-line presentation of handbooks, standards documents, software manuals, and maintenance aids.

Hypertext design and technology: The elements of hypertext, and software and hardware to support its implementation.

Hypertext development: Practical advice for designing hypertext capabilities into information systems.

The report is 88 pages and includes 17 figures. The cost is $75. To order, contact the CSERIAC Program Office.

CALENDAR

Oct. 15-17, 1991
San Diego, CA
11th Annual International Display Research Conference, sponsored by the IEEE Electronic Devices Society, Society for Information Display, and Advisory Group on Electron Devices, at the Hyatt Islandia. Contact Palisades Institute for Research Services, Inc., Attn: IDRC, 201 Varick St., New York, NY 10014; (212) 620-3375, Fax (212) 620-3379

Oct. 20-23, 1991
Dearborn, MI
Vehicle Navigation & Information Systems '91, organized by IEEE. Contact Steven E. Underwood, University of Michigan, 4110 EECS, Ann Arbor, MI 48109-2122; (313) 764-4333, fax (313) 763-1503

Dec. 15-18,1991
San Antonio, TX
Hypertext '91, sponsored by the Association for Computing Machinery SIGLINK, SIGCHI, SIGOIS, and SIGIR. Contact John J. Leggett, General Chair, Hypertext Research Lab, Dept. of Computer Sciences, Texas A & M University, College Station, TX 77843-3112; (409) 845-0298, fax (409) 847-8578, Email:leggett@bush.tamu.edu

Feb. 18-21, 1992
Miami, FL
3rd International Conference on Management of Technology, sponsored by the University of Miami and the Institute of Industrial Engineers. Contact Tarek M. Kahalil, Industrial Engineering Dept., University of Miami, P.O. Box 248294, Coral Gables, FL 33124-0623; (305) 2284-2344

Apr. 7-10, 1992
Southampton, England
The Ergonomics Society 1992 Annual Conference, at the Aston University and Business Centre. Theme: "Ergonomics For Industry." Contact E.J. Lovesey, Lynton, Horseshoe Lane, Ash Vale, Aldershot, Hants GU12 5LJ; 0252 24461 ext. 4082. Abstract Deadline: October 4, 1991

Notices for the calendar should be sent to CSERIAC *Gateway* Calendar. CSERIAC Program Office, AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573, at least four months in advance.

Modeling Human Force Response (Concluding Studies)

Norman S. Phillips

This is the third and final article of this series. In the first article a simple model was found that was capable of replicating the measured vertical force and pitching moment response of a live subject acted upon by a +Gz triangular deceleration impact. The second article indicated that the same type of representation could be used to replicate the spinal force and pitching moment response of a live seated human when subjected to a -Gx triangular deceleration. This latter model, the "Gx model," was shown to be an adequate predictor of human force and moment response to +Gz impact, although it was not as accurate a predictive tool as was the "+Gz model." The +Gz model could not accurately predict human response to a -Gx input deceleration.

The models developed were single-mass particle models supported by three visco-elastic elements. The mass of the particle was that of the subject, and the location of the center of gravity was that of the subject for the +Gz model and was 6 inches above the center of gravity for the -Gx model. These were found to provide a simplified means of estimating the response of the human for systems which require a load sensing feed-back loop to control the system. The pursuit of the simplified model began with the development of the U.S. Air Force's Crew Escape Technologies Program (CREST). Advanced escape systems with the capability to actively control their trajectories need a predictive tool to provide accurate force and moment information as a function of time to the onboard computer. By having one mass attached to the seat pan and to points indicative of the shoulder strap attachment points, the model's response to deceleration in terms of resultant force and moment replicates that of the human. The model has one inertial mass and three links to the seat. There is no need for complex multi-segment models to be coded into the system's response prediction routine.

The last step of the whole-body modeling process was to study the response of the live human to a lateral (Gy) acceleration. It was hoped that the assumed single-mass model might be usable, although it was apparent from the beginning that the dynamics of the torso in the spinal direction would be less a factor in the force response for this environment than would the whole body motion within the harness. The desire was still to find a simple model, one which might also be applicable to another environment.

The required live human subject data for the lateral acceleration environment were found again by using the Biodynamics Data Bank at the Armstrong Laboratory (AL; formerly the Harry G. Armstrong Aerospace Medical Research Laboratory, AAMRL). The data were available from tests conducted as part of the evaluation of a proposed, modified, F/FB-111 restraint system. The results of the study were reported in AFAMRL-TR-80-52, *Evaluation of a Proposed, Modified F/FB-111 Crew Seat and Restraint System.*

Fourteen subjects had participated in a lateral test series conducted at a nominal 8 Gy deceleration. The experiment had been conducted for one restraint system at two shoulder harness angles and two seat back angles. Thirty five channels of data were collected during the tests. The seat pan had been instrumented with triaxial accelerometer packages, as were the head and chest of the subject. The left, right, and crotch straps were instrumented as were the left and right inertial reel, and the reflected straps. The seat pan had been instrumented with three vertical force cells, two drag load cells, and one side-force load link. The foot support had been instrumented with three load cells, each recording forces in the three orthogonal axes. One channel had been allocated for the velocity of the sled. High-speed photographic data had been collected. The seat back had not been instrumented, and this fact caused some concern.

The data examined were for a 166-pound subject seated at a back angle of 90 degrees with a shoulder harness strap angle of 0 degrees. The restraint harness was the operational F/FB-111 restraint system and the acceleration was approximately a square wave acceleration of about 8 G magnitude with a duration of 100 milliseconds. The subjects had been instructed to brace themselves for the impact by pressing their helmets against the head rest, hands against interior thighs at the knees, and feet against the footrest.

All data channels were examined to determine the necessary conversion to one global coordinate system. From the data, it was apparent that several of the force vectors would have to be established using the photographic data and the subject anthropometry. After that, it was still necessary to assume a redundant load in the measurement system. Preliminary examination of the force information collected at the seat pan indicated that vertical forces were measured in both compression and tension at a surface where only compression loads were to have been measured. Further study indicated that

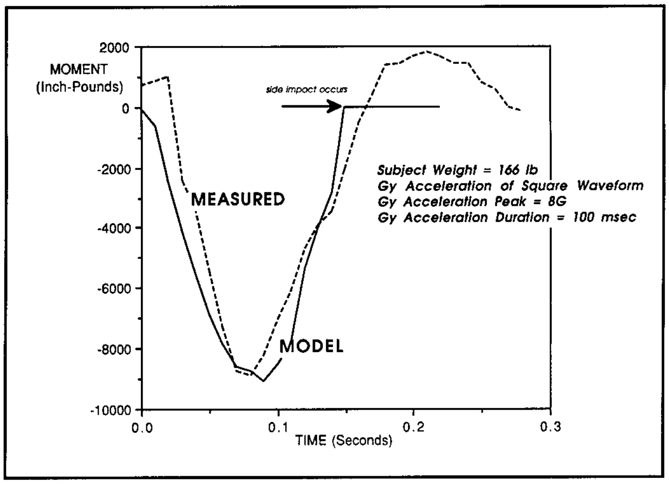


Figure 1. Computed rolling moment response (model) compared with measured rolling moment (subject response)

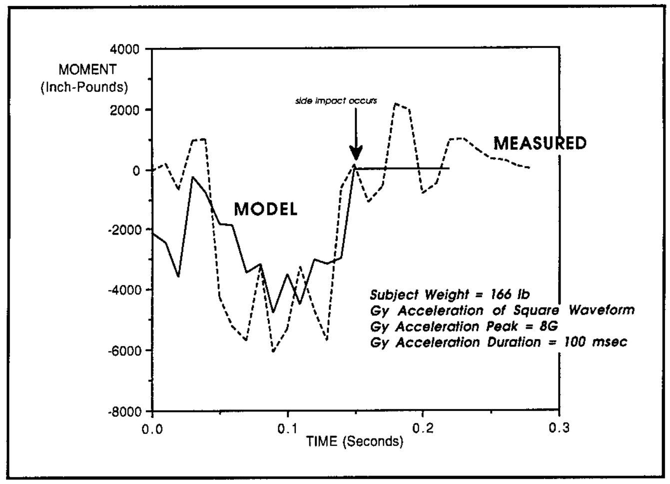


Figure 2. Computed pitching moment response (model) compared with measured pitching moment (subject response)

to permit the measurement of tensile forces, which did occur, a small slender rod had been added to the vertical load cells of the seat pan to prevent the lifting of the surface from the load cells. The rods were small, but it was never established how the shearing rigidity of the rods influenced the measurement of forces in the plane of the seat pan.

A digital program was written to accept the measured data and transform it into the net forces and movements along and about the orthogonal axes. Preliminary results indicated a large imbalance in both the lateral and fore-and-aft directions. The fore-and-aft forces were imbalanced by a force and magnitude indicative of the preload created by the subject prior to impact. Both the pre- and post-impact imbalances were satisfied by assuming that a pre-load force acted through the feet and through a point at shoulder height of the subject. It was assumed that the pre-load magnitude varied linearly from the pre-test imbalance force to the post-impact imbalance force level, and that its location was at the shoulders. This assumed location created the correct pitching moment about the seat reference point for the static values.

The processed information indicated significant differences between the net forces measured and their anticipated body accelerations, and the acceleration levels measured at the head and chest. The differences were sufficient to question the validity of any measurement relying upon the net forces measured in the plane of the seat pan. Only those values extracted from any vertical force component measurement were not suspect. Therefore, the only usable measurements were those indicative of the rolling and pitching movements and the vertical force. Any redundant horizontal forces caused by the vertical cells would create little effect in pitching and rolling about the seat reference point.

The single-degree-of-freedom model, described previously, had been programmed to accept the lateral input acceleration from the data files and was used to find a best fit configuration. The single mass has the mass of the subject and the strap attachment points are still as previously located. However, the center of gravity must be placed further forward, 12 inches from the seat reference point (SRP), and lower than before, 6 inches above the SRP. This model has significantly different frequency response characteristics from the previous models.

The results shown in Figures 1 and 2 indicate the capability of the selected model to fit the rolling and pitching moment measured. The vertical force was not studied because the resultant vertical force variation was small. The rolling moment predicted would theoretically impact the sides of the seat at the location where the response is horizontal. This is similar to the results seen in the fore-and-aft response curves of the previous paper. In practice, it is necessary to restrict the moment of the mass by the envelope of the seat. The pitching moment calculated response is the same shape as the measured response, but it provides the least favorable comparison with measured data. The general waveform of the measured data can be seen in that computed from the model, but the measured data contain higher frequency information than the single-degree-of-freedom model is capable of providing.

The frequency response characteristics of the model are 8.5 Hz and a damping ratio of 2.5 in the spinal direction, 3.7 Hz and 2.1 damping ratio in the fore-and-aft direction, and 3.3 Hz and a damping ratio of 2.3 in the lateral direction. The vertical natural frequency is similar to that of the best-fit vertical response model, the fore-and-aft frequency response is similar to that of the best-fit fore-and-aft model, and the lateral response cannot be comfortably compared with any other model since it was the lateral test data which was to have established that natural frequency. The tests where impact was conducted along the other axes did not have any significant lateral input acceleration to "excite" that mode of response.

The lateral model was used with the acceleration inputs of the previous papers to investigate the capability of

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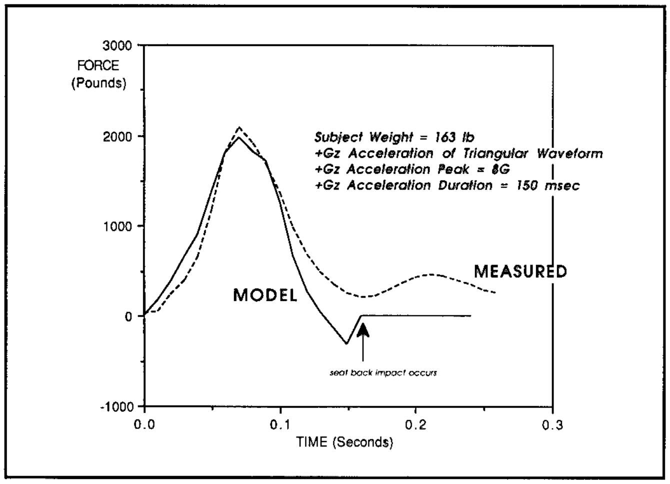

Figure 3. Computed vertical force response (Gy model using +Gz input acceleration) compared with measured vertical force (subject response)

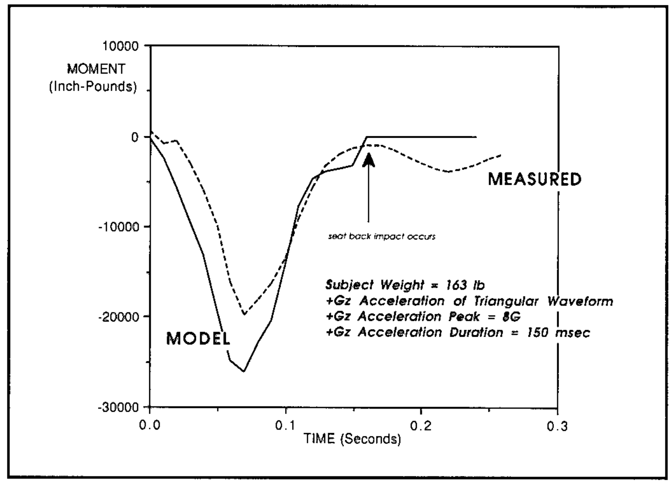

Figure 4. Computed pitching moment response (Gy model using +Gz input acceleration) compared with measured pitching moment (subject response)

the model to replicate the response of the human to +Gz and -Gx inputs. Figures 3 and 4 present the response of the model to the +Gz input of the original paper. The curves indicate that the vertical response predicted matches that measured in both phase and magnitude. The pitching moment response is in phase with the measured data but has a magnitude that is too great. The results are similar to those of the previous paper where the fore-and-aft -Gx model was used with the vertical acceleration. Use of the lateral (Gy) model with the fore-and-aft acceleration produces results that are less favorable.

The research conducted in whole-body modeling was designed to exhaustively study the nature of the measured data, transform the data into an inertial coordinate system, and then use the data for comparison with the predicted response of a simplified model. The analysis led to development of data processing routines for each of the test environments for which there was reliable and complete data, and to development of programs for predicting force and moment resultants for all translational acceleration inputs. Lack of time and funding restricted the analyses to only one specific test for each acceleration environment. Each was selected for similar input acceleration magnitudes and durations, and for similar subject weights.

The results of this research indicate that it is possible to use the single-mass model to predict live human force and moment response to each of the three orthogonal and translational input accelerations, independently, and that it may be possible to use one model for two translational inputs simultaneously. For example, it may be acceptable to use the "best" fore-and-aft (-Gx) model for both vertical and fore-and-aft accelerations combined. It may be possible to use the "best" lateral (Gy) model for combined vertical and lateral input accelerations.

An additional feature of the simple models may be that their geometrical nonlinearity provides a response that moves toward injury prediction capability. The models, including the lateral model discussed in this paper, have frequency response characteristics that are raised or lowered in displacement directions consistent with current models of injury prediction for each of the individual coordinate axes. This suggests that one model may, in fact, be capable of predicting both force and injury potential for any translational input acceleration.

There is a wealth of information in existing databases that is available for analysis. With thorough and patient investigation it is possible to fully understand each data channel's function and effect upon the calculation of whole body kinetic response for a live human subject. There are many potentially valuable studies which could begin today to evaluate the effects of the weight, the restraint system, and changes to the acceleration profile. Beyond that, there should be studies on the effects of off-axis translational accelerations and of combined rotational effects, which have been ignored, but surely exist, in real ejections and crashes.

Although one unique model with the capability to predict kinetic response for all environments was not found, it has been demonstrated that a simplified model can be used for selected environments. How well the model works for the population of air crew members and the spectra of input accelerations will have to await more analyses and some statistical validation.

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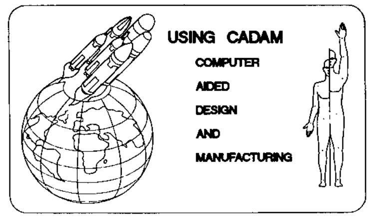
Multi-User Human Computer Modeling - A Mixed Blessing

Richard C. Davids



Releasing a set of 2D, 3-view human computer models (HCMs) into the largest single main-frame computer-aided design and manufacturing (CADAM) system was a real eye-opener. Over 1,000 trained CADAM operators now had access to 5th and 95th percentile female and male anthropometric manikins. Previously trained to design missile hardware, facility layouts, and detail drawings, CADAM engineers could now rotate, translate, scale, twist, and turn these manikins to the limit.

In 1983, the Lockheed Missile and Space Company Human Factors Engineering Department entered the mainstream CADAM environment. The Trident II Fleet Ballistic Missile System was in the design and development stage. Air-bearing mechanical support equipment, translation fixtures, dollies, hoisting equipment, and heavier missile hardware were necessary. It was time to replace arm-waving in design reviews and plastic manikins with an electric human factors tool. The ability to depict operational situations such as sitting, standing, and bending in operational and maintenance postures seemed a valuable incentive. Thus we had to provide a tool with a purpose for mechanical, electrical, facility, and field engineers. We had to put the human back into the loop.

After one 10-hour CADAM class and 300 hours of research and design time, a simple male HCM emerged in plan, elevation, and front views. Creating this HCM was a classic trade-off between ease of use and fidelity of simulation. The HCM had to be simple to use and compatible with the traditional engineering design format, yet representative enough of the user population to accurately predict reach envelopes, safe storage arrangements, and operational manpower requirements. A sophisticated, kinematic, highly accurate HCM might require user-manuals, training, and a separate computer environment.

The intent was to create a tool which experienced (more than 250 hours) CADAM operators could use without either learning any new CADAM programming skills or entering a special computer environment outside of the main-frame computer system. Thus only the existing CADAM drafting routines to design and manipulate (scale, rotate) the HCM were used.

Over 70 static and dynamic anthropometric measurements representing at least a dozen different databases from NASA Publication 1024 were used to create the HCM. Unfortunately, no single sample contained the necessary geometry in all views to construct a 2D, 3-view human computer model. Thus it ended up being a real tri-service, "Heinz 57" variety, model which used dimensions obtained from several military anthropometric databases.

One less obvious but important factor in the design was to have the HCM appear as human as possible given the point-to-point, circle, line, and spline drafting elements. Its acceptance among the engineers would depend on how well people could visually identify with it. Perhaps the novelty of a curvilinear, gender-specific figure juxtaposed in the rectangular, hard-cornered world of trunnions, motor chocks, rail cars, and equipment sections provided some visual relief.

To facilitate acceptance, this HCM was created and stored as electronic "details" or "blocks" which could be used in solo or multiple instances. Several features were created to make it easy for naive but intelligent CAD users to apply the manikins. A rough order of magnitude (ROM) scaling factor was calculated to scale the manikins from 5th to 95th percentiles, as shown in Figure 1. A library of human CADAM "parts" was created. Outlines of human figures reaching, kneeling, sitting, and standing were segregated into 10 drawings, each with about 6

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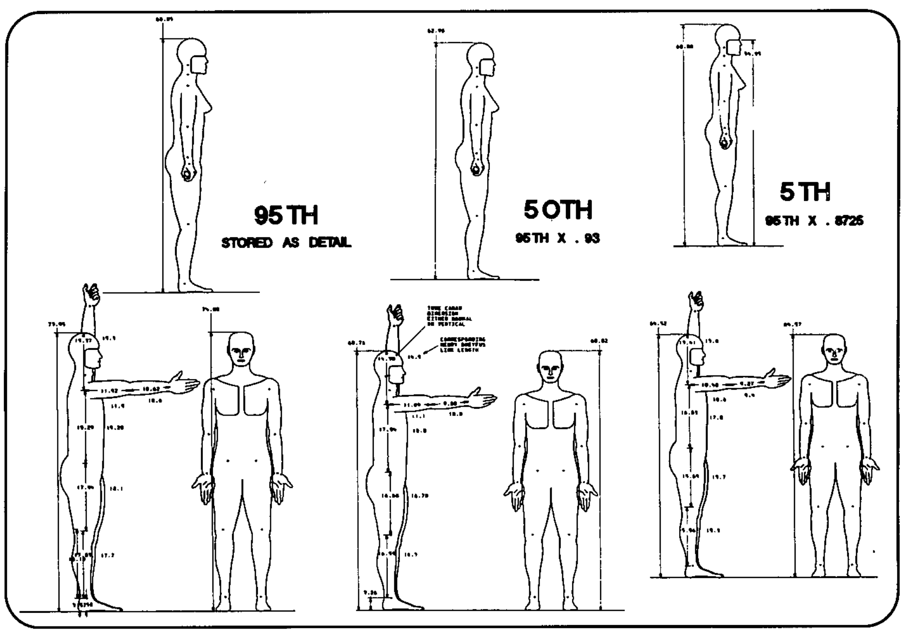


Figure 1. ADAM and EVE anthropometry scale factors

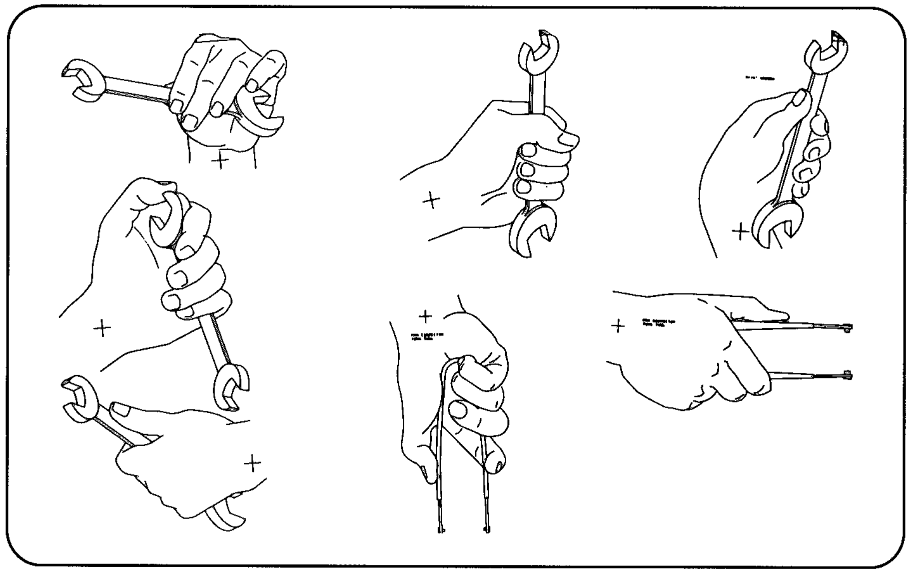


Figure 2. ADAM hands and tools

separate "details". As shown in Figure 2, orthographic, quasi-isometric drawings of hands holding wrenches and other tools were added.. Pivot points for links were identified with engineering-style symbols, like rivets, to provide a rudimentary kinematic capability for articulating body segments. All were stored as 95th percentile figures with scaling factors depicted on the face of the drawing in text.

A serious effort was made to spread the word about this "new" CAD technology. Presentations were made to Lockheed user groups, such as the Departments of Mechanical Missiles, Mechanical Support Equipment , and Missile System Training. Articles were published in the company newspaper. Press releases were issued.

What evolved was less than expected, but extremely encouraging. The HCMs usually appeared in top-level, conceptual layout drawings. These drawings were constructed by design engineers outside of systems engineering, the home department of human factors engineering. The HCMs appeared without solicitation, coercion, or intimidation. Support equipment designers put golf hats and pants on the male HCM, perhaps because he was too gender-specific. The female HCM seldom appeared in the early drawings, clothed or not. Very few engineers took time to articulate the segments and experiment in anthropometry and kinematics. Most HCMs appeared as side views to show relative scale, simple overhead and forward reach, and line of sight to hardware control panels.

Early success with the HCM came with showing operational access to design engineers two years ahead of field tests and for a fraction of the cost of partial or full-scale mockup exercises. For instance, the HCM was critical in showing the severe consequences of stowing heavy hardware in rail cars. Trident II rocket motors are transported in rail cars and their motor chocks and end-rings must be secured together with end-blocks. These large, 40 lb. end-blocks, which secure 20 ft. long tie-rods to the end-rings, were to be stowed in toolboxes on the floor of the rail car. When questioned why, the design engineer replied: "Engineers always have toolboxes!" The HCM was used to show the awkward access and personnel safety hazards of lifting heavy items out of toolboxes. Instead, human factors recommended wall-mounting the rods and heavy items at more accessible work heights based on the HCM analysis (see Fig. 3). The recommendation prompted a re-design. The simple HCM was used to improve the Trident II first level of maintenance, and to design both the Space Station Freedom and numerous command control centers, including the DoD Office of the Secretary of Defense (OSD) Crisis Coordination Center and Advanced Tactical Fighter, YF-22A.

The HCM became a great communicator, the common ground, for human factors engineers and the dozens of engineering disciplines responsible for designing military systems. It added the human dimension to design. Bill Shea, the Lockheed on-site Program Manager for the OSD Crisis Coordination Center, said: "It brought credibility and the latest technology together in presenting a cohesive whole design." Maybe that's what it's all about.

Richard Davids is a Human Factors Staff Engineer at Lockheed Missile & Space Co., Sunnyvale, CA. ●

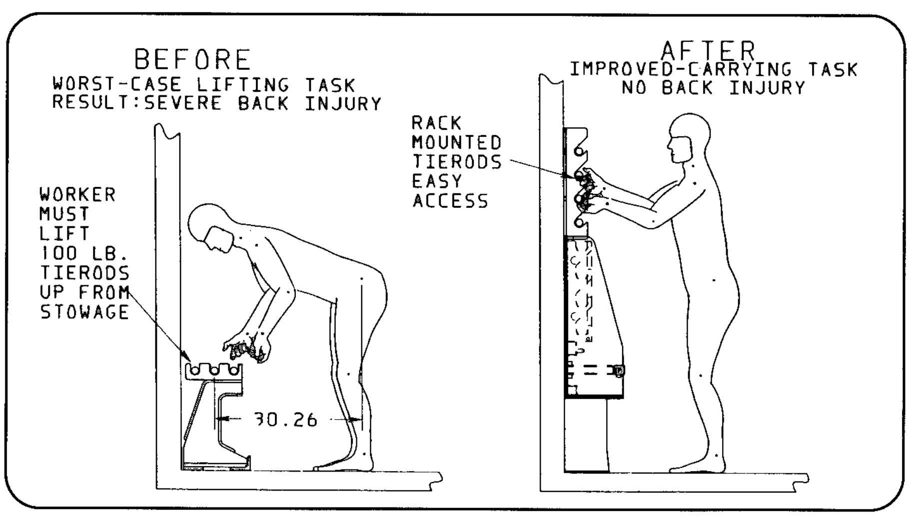


Figure 3. Lift vs. carry access

Workshop and Proceedings for
Future Performance Measurement Needs

Robert D. O'Donnell

Modern systems, especially military systems, continue to increase in complexity at an astonishing rate. Although systems have become highly automated, they still depend ultimately on the human to achieve mission success. The task of the human engineer, faced with assessing the performance capability of the person/machine system, is much more complex today than in the past. For instance, in modern fighter aircraft, speed and precision requirements are more critical, and the cognitive component of the workload has become much more important.

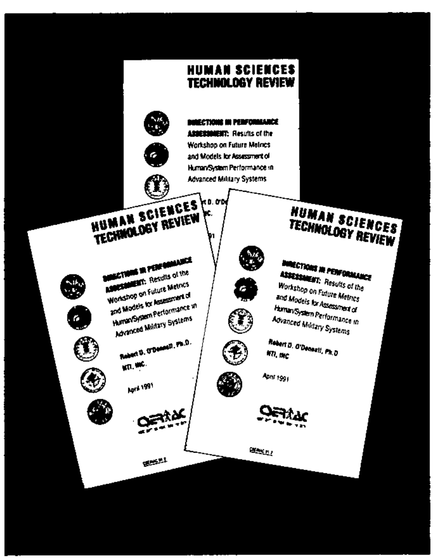
Assessing the interaction between these requirements challenges the most advanced performance assessment metrics. When one moves from single systems to whole military operations, the problem becomes even more demanding. Complex military operations, involving on-line simulation and multiple forces located in geographically different locations, will certainly strain the ability of the human factors engineer to assess both individual and system performance.

The Armstrong Laboratory (AL; formerly the Harry G. Armstrong Aerospace Medical Research Laboratory, AAMRL) at Wright-Patterson Air Force Base, Ohio, has begun to raise questions concerning the adequacy of existing performance assessment paradigms and techniques to respond to this increased complexity.

To explore these questions, AL sponsored a "Workshop on Future Metrics and Models for Assessment of Human/System Performance in Advanced Military Systems" 24-25 July 1989. This workshop brought together 10 active researchers from a variety of disciplines, including human factors and experimental psychology, cognitive psychology, artificial intelligence, physics, and medicine. These individuals were asked to consider the kinds of systems which could be anticipated in the military over the next 20 years, and to recommend performance assessment paradigms, approaches, and methodologies which might make AL better prepared to respond to these changes.

Discussions during the two-and-one-half day session covered a variety of potential techniques. These covered existing subjective, behavioral, and physiological approaches to measurement. Advanced techniques such as the magnetoencephalogram (MEG) and positron emission tomography (PET) were also discussed, as well as current and advanced modeling techniques and analytical tools. A series of specific recommendations emerged involving each of these procedures.

Somewhat surprisingly, there was a general consensus among this group of diverse researchers that traditional experimental control, as exemplified in reductionist models of experimentation, may be inappropriate in the future. It was felt that the incredible complexity of future systems and operations will frustrate any attempt to develop single-variable or even current multi-variate designs.



Directions in Performance Assessment: Results of the Workshop on Future Metrics and Models for Assessment of Human/System Performance in Advanced Military Systems (O'Donnell, 1991)

Any attempt to reduce this complexity to "manageable proportions" will introduce artificiality, and change the nature of interactions among variables to the point where results will be useless in any practical sense. While traditional experimental designs may continue to yield valuable basic data, the workshop strongly recommended that more naturalistic designs need to be developed.

But what form might such designs take? The workshop made strong recommendations concerning the need to concentrate on development of enhanced subjective assessment techniques as a way to broaden the real-world relevance of experiments. Participants were impressed with emerging techniques to incorporate methods such as multi-dimensional scaling and verbal protocol analysis into complex designs.

Subjective assessment and expert opinion can serve as an integrator of a vast quantity of otherwise disjointed information. The problem, traditionally, has been the unreliability of these techniques. However, it was felt that the newer approaches can objectify the individual's subjective responses to an acceptable level. Such subjective approaches were seen as a potential cornerstone of naturalistic designs.

Considerable discussion concerned the need to evolve new analytical tech-

Continued on page 14

niques for integrating individual kinds of data into an operationally meaningful metric. It is one thing to measure a subject's reaction time or heart rate, and quite another to convert that measurement into an estimate of how the system will perform in the field. To do this, mathematical and computer-based approaches for integrating behavioral and physiological measures, and combining them with advanced subjective measures and outcome data, are needed. Neural net technology, in particular, was singled out as having the potential to provide such an integration.

However, it was recognized that other approaches (e.g., Chaos Theory) could eventually serve this function. A major recommendation was that investigation of the utility of such approaches be increased. Ultimately, it was concluded that computer models, ranging from "top-down" models to models of cognitive function, would provide an increasingly important experimental design technique.

Whatever its ultimate form, it was emphasized that new approaches to integrating individual experimental results and individual variables collected in the context of a complex experimental design were required. There was some feeling that these approaches would be "non-algorithmic" in the traditional sense, and it was clearly recognized that the level of mathematical sophistication of most human factors engineers was inadequate to handle this kind of integrated measurement.

Given this result, the workshop ended with a strong recommendation that a continuing multi-disciplinary interaction be encouraged through formal continuation of meetings and workshops. A specific plan for this was recommended by the workshop participants.

In view of the complexity of the problem, the conclusions and recommendations of this workshop were impressively specific. Obviously, it is impossible to tell whether the specific recommendations will prove productive. However, the workshop participants were willing to take bold steps in predicting future directions.

There is no doubt that their recommendations will stimulate considerable discussion, and hopefully, productive directions in the future.

The proceedings of this workshop (shown in fig.) are available as a Human Sciences Technology Review through the CSERIAC Program Office for $25.

Robert D. O'Donnell, Ph.D., is President and Senior Program Manager of NTI, Inc., Dayton, OH. ●

CSERIAC Technical Information Services: What are They? How Do They Work?

Christopher J. Sharbaugh

Most inquiries begin with a simple phone call to the CSERIAC Program Office. Upon calling, you will be referred to one of our technical analysts: Ron, Larry, Mike, Cindy, Trudy, Chris, or Mark. They will work with you to determine the type of technical service you need. They may recommend a *Search and Summary*, a *Review and Analysis*, or a *Technical Area Task*, depending on the amount and type of ergonomic expertise required. Some of the steps involved are depicted in the figure below.

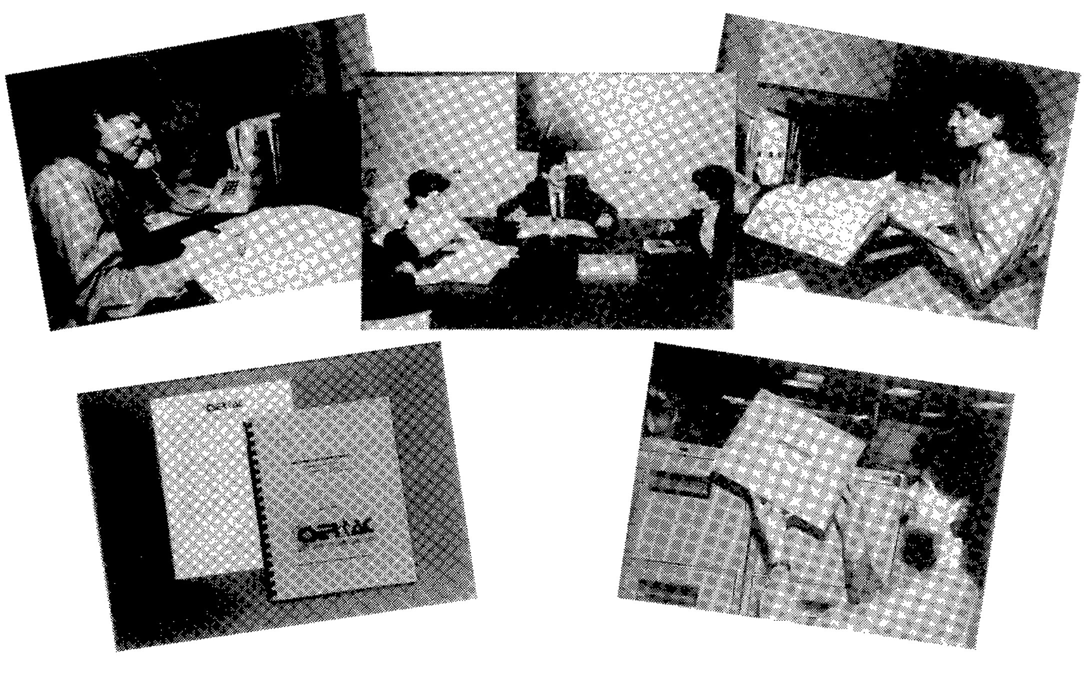
A *Search and Summary* is our primary level of analysis. Suppose a client is looking for information on performance differences between different display types. The client and analyst work together to create a customized strategy for a literature search. This strategy is used in searching many databases, for example, Defense Technical Information Center (DTIC), NASA, PsycInfo, Compendex, among others. Then, the analyst reviews and edits the initial print-out of citations and abstracts. As a result, a refined literature search is produced and bound in a booklet, and sent to the client. In addition, a listing of the most pertinent citations, and excerpts from cited articles found in our in-house library are sent to the client.

The aforementioned inquiry can also be answered in much greater detail and depth, called a *Review and Analysis.* Basically, a *Review and Analysis* is an extension of a *Search and Summary.* Similarly, the client and analyst work together to create a strategy for a literature search. The analyst uses the literature search to acquire articles for critical review, and to consult references in our in-house library. The analyst also contacts subject-matter experts. This information is compiled into a 3-6 page paper that synthesizes the results of our technical review, and this is sent to the client. The points-of-contact for subject-matter experts, literature search, and complete articles or exerpts are included as well.

A *Technical Area Task* is a project initiated by a client who needs a level of analysis greater than a *Search and Summary* or *Review and Analysis.* These are initiated through special arrangements with the CSERIAC Program Office. These may include the writing of a state-of-the-art report (SOAR), organization of a workshop of subject-matter experts, or creation of a handbook. The scope of the task that can be performed is almost limitless.

For more information about these services, contact the CSERIAC Program Office at (513) 255-4842 or DSN 785-4842.

Chris Sharbaugh is a Technical Analyst at CSERIAC and Assistant Editor, Gateway.



CSERIAC technical information analysis services involve interacting with the customer, consulting with subject-matter experts, reviewing documents and reference works, documenting findings, and sending a complete report to the customer

Summer 1991

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